# New proposal for slippage calculation along the subduction fault of Tokai district, Central Japan

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## 1 Introduction

Tokai earthquake is a possible future disastrous earthquake feared to bring serious damage to Japan. The Tokai district, central Japan, is located close to the convergent boundary between the Philippine Sea (PHS) slab and the Eurasian (EUR) plate. In this zone, the PHS subducts beneath the EUR from the Sagami and the Nankai-Suruga troughs.

Analytical approaches for treatment of faults in crustal deformation analysis involve some limitations. One important limitation of these methods is the idealization of uniform dislocation on a rectangular fault plane in a uniform medium or half space. In fact, the real source is more complex than that supposed in the model and therefore, only the first-order aspects of the source characteristics can be derived from a uniform dislocation model. Isotropic and homogeneous material properties are the main assumption of these methods and they consider a flat ground surface with no topographical features as a semi-infinite domain.

The FEM on the other hand, allows easy treatment of complex boundary shapes and internal variations of material properties. The FEM can simulate source geometry flexibly, and it's also able to regard topographic configurations.

## 2 Motivation

The spatial distribution of the strength of interplate coupling between the PHS plate and continental plate in the Tokai district was investigated in detail through the inversion analysis of geodetic data by some authors. During an interseismic period, a region at an intermediate depth remains locked, while the shallower and deeper portions are decoupled, and a steady slip proceeds there. Decoupling is dominant along shallower and deeper portions of the plate boundary because of high pore pressure due to the existence of water and low viscosity due to high temperature, respectively. Such a situation can be expressed as the superposition of a uniform steady slip over the whole plate boundary and a back slip in the locked region.

Since the steady state subduction solution does not contribute to strain or deformation changes on the surface of the overthrust plate, the deformation there during the strain accumulation phase is indistinguishable from that produced by normal (or back) slip on the main thrust zone. Therefore, deformation observed on the surface of the overriding plate (e.g., from GPS detection) is almost equivalent to that produced by the slippage alone.

## 3 New Method

Here, we can express observation equations with $N$ observation data as:

$$x_i = \sum_j b_{ij} u_j + e_i \qquad (i = 1, \dots, N) \tag{1}$$

where $x_i$ are observed surface deformations, $u_j$ are slipping components along the subduction fault (interface zone of two plates), $e_i$ are random errors, and $b_{ij}$ are Green's function (i.e., elastic response at a point $i$ to a unit slip at a point $j$ on the model source region or interface zone). Equation (1) can be rewritten in matrix form as:

$$\boldsymbol{X} = \boldsymbol{BU} + \boldsymbol{E} \tag{2}$$

where $\boldsymbol{B}$ is a $N \times M$ coefficient matrix. To minimize the errors, the length of vector $\boldsymbol{E}$ has to be minimized as:

$$\boldsymbol{F} = |\boldsymbol{E}|^2 = \boldsymbol{E}^T \boldsymbol{E} \rightarrow \boldsymbol{min} \tag{3}$$

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where

$$\boldsymbol{F} = (\boldsymbol{X}^T - \boldsymbol{U}^T \boldsymbol{B}^T)(\boldsymbol{X} - \boldsymbol{B}\,\boldsymbol{U}) \qquad (4)$$

could be minimized by:

$$\partial \boldsymbol{F} / \partial \boldsymbol{U} = \boldsymbol{0} \qquad (5)$$

which results in:

$$\boldsymbol{U} = (\boldsymbol{B}^T \boldsymbol{B})^{-1} \boldsymbol{B}^T \boldsymbol{X} \qquad (6)$$

This relation offers a straightforward way for finding slippage vector $\boldsymbol{U}$ at the interface. The new aspect of the present study is estimation of Green's function $\boldsymbol{B}$ by means of FEM. This issue enables us to overcome all limitations of traditional *Inversion methods*.

## 4 Green's function by FEM

Figure 1 schematically shows FE mesh of a model containing two converging plates. To implement fault sliding in a continuum-based FEM program, *Split Node Technique* as a simple and efficient method is applied. This method does not increase the number of degrees of freedom and no net forces or moments are induced on the finite element mesh when isoparametric elements are used.
How to find the Green's functions by the FEM? By applying unit slippage vectors in each degrees of freedom of the interface nodes, the relevant response of ground surface nodes determines corresponding component of the coefficient matrix $\boldsymbol{B}$.

## 5 Boundary conditions

Any constraint on the FE model as boundary condition could be proposed as a spring. If the stiffness coefficient of this spring is assigned to be zero, it induces a free movement in corresponding degree of freedom. On the other hand, an infinite value for the stiffness coefficient provides a fix condition in corresponding degree of freedom.
In present study, we attempt to represent a kind of fictitious boundary condition exploiting the concept of springs. This methods covers all truncated boundaries of FE model by a set of springs whose stiffness coefficient are initially unknown. These stiffness coefficients are investigated in a manner that a plausible pattern of problem's components could be reproduced by model.

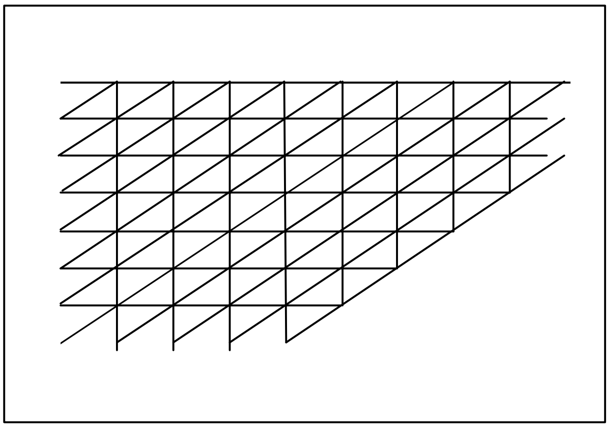

***Figure 1.*** Finite Element mesh of two converging plates. The thick inclined line indicates the subducting fault.

All lowermost nodes of the PHS plate are restrained in the vertical direction implying the existence of a relatively rigid enough layer beneath the oceanic crust.
PHS plate-Pacific plate Coupling and westward-movement of the Pacific plate could be regarded as one cause of the PHS plate's movement. Mantle convection on the other hand partially has remarkable role in the PHS plate's movement. These factors are taken into account by introducing nodal tectonic forces on the southern and eastern lateral sides of the PHS plate.

## 6 Concluding remarks

In summary, the present method proposes a direct method for estimation of slippage vectors at the interface zone. This method on the other hand suffers from unknown values of tectonic forces and stiffness coefficients of spring elements. So, a trial-and-error method should be implemented for obtaining proper quantities of boundary conditions.